METHOD OF CONNECTING FLAT CABLE TO CONNECTING TERMINAL, CONNECTING APPARATUS, AND CONNECTING STATE DETERMINING METHOD

Field of the Invention

The present invention relates to a method of connecting a flat cable to a connecting terminal, a connecting apparatus, and a connecting state determining method.

Background of the Invention

A conventional wire harness for use in a vehicle is typically comprise of wires each having a conductor of circular shape in cross-section covered with an insulating material. To establish electrical connections between wires of a wire harness or between wires and vehicle-mounted electrical equipment units, connecting terminals are attached to the conductors of the wires by means of crimping or insulation displacement.

To determine pass/fail of a crimping state or an insulation displacement state of the connecting terminal with the conductor, a method is known which takes advantage of a load pattern that changes with time during an operation of attaching a connecting terminal to a wire (Japanese Unexamined Patent Publications Nos. Sho 63-281071, Hei 10-125437). Based on such a determining method, a quality control system has also been established.

In recent years, with the trend of a complicated installation of wires and a reduction in size of connecting terminals, flat cables have been used in place of the conventional wire harnesses, and new connecting terminals called pierce terminals have been used corresponding to the flat cables.

The flat cable used in place of the wire harness is utilized in a module which is disposed in a narrow space or

integrated with a vehicle component such as ceiling, door, and dash board. As shown in Fig. 17, a flat cable 1 has flat conductors 1a arranged in parallel and covered with an insulating material 1b. The conductors 1a are made, for example, of copper, aluminum or the like of 0.15 to 0.2 mm in thickness and approximately 1.5 to 2.5 mm in width Wc. The insulating material 1b is, for example, a polyethylene terephthalate (PET) film of 0.09 mm in thickness, or a less expensive polybuthylene terephthalate (PBT), or the like.

As shown in Fig. 18, a connecting terminal 3 has crimp pieces 3b arranged to opposite to one another on both sides of a substrate 3a and is provided at one end with a female terminal 3c. The substrate 3a is slightly narrower than the conductor 1a in width Wt which is set, for example, in a range of approximately 1.2 to 2.0 mm. Fig. 19 shows a connecting terminal 5 which has a female terminal 5c and crimp pieces 5b alternately arranged on a substrate 5a.

To connect the connecting terminal 3 to the flat cable 1, the crimp pieces 3b are pierced into a desired conductor 1a at desired positions, and the leading ends of the penetrating crimp pieces 3b are bent inward in an arc shape to hold the desired conductor therebetween. In this way, the connecting terminal 3 is electrically connected to the desired conductor 1a of the flat cable 1.

The flat cable 1 having the connecting terminal 3 connected to the desired conductor 1a in the above manner poses a problem that an electrical connection between the conductor 1a and the crimp pieces 3b is not stable, thus entailing a variation. In addition, with regard to the connection with the flat cable 1 and the connecting terminal 3, no method has been established for determining pass/fail of the connection, although a determination method is established for the conventional connecting terminal. Thus, the provision of a method of determining a connecting state

has been desired.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method of connecting a flat cable to a connecting terminal, which achieves a stable electrical connection between a conductor of the flat cable and crimp pieces of the connecting terminal, a connecting apparatus, and a connecting state determining method.

To achieve the above object, according to one aspect of the present invention, there is provided a method of connecting a flat cable to a connecting terminal, in which the flat cable having a plurality of flat conductors, arranged in parallel and having surfaces thereof covered with an insulating material, is connected to the connecting terminal, by piercing a plurality of crimp pieces, formed integrally with a substrate of the connecting terminal, into a desired conductor of the flat cable and by inwardly bending leading ends of the crimp pieces penetrating the flat cable to hold the desired conductor therebetween. The method comprising the steps of piercing the crimp pieces into the desired conductor with a gap left between the substrate and the flat cable, and bending the leading ends of the crimp pieces while maintaining a contact position unchanged at which each of the crimp pieces penetrating the conductor is in contact with the conductor.

Preferably, the crimp pieces are urged simultaneously from the substrate and from the leading ends of the crimp pieces when the leading ends are bent.

Preferably, an urging force for urging the substrate is set to be larger than an urging force for urging the leading ends of the crimp pieces.

According to another aspect of the present invention, there is provided a method of connecting a flat cable to a

connecting terminal, in which the flat cable, having a plurality of flat conductors arranged in parallel and having surfaces thereof covered with an insulating material, is connected to the connecting terminal, by piercing a plurality of crimp pieces, formed integrally with a substrate of the connecting terminal, into a desired conductor of the flat cable and by inwardly bending leading ends of the crimp pieces penetrating the flat cable to hold the desired conductor therebetween. The method comprises the step of forming cut ends in the desired conductor by means of the plurality of crimp pieces pierced into the desired conductor, each cut end extending along an inner face of a corresponding one crimp piece and in contact with the inner face with a constant contact pressure over substantially the entire length of the cut end.

According to a further aspect of this invention, there is provided a method of connecting a flat cable to a connecting terminal, in which the flat cable, having a plurality of flat conductors arranged in parallel and having surfaces thereof covered with an insulating material, is connected to the connecting terminal, by piercing a plurality of crimp pieces, formed integrally with a substrate of the connecting terminal, into a desired conductor of the flat cable and by inwardly bending leading ends of the crimp pieces penetrating the flat cable to hold the desired conductor therebetween. The method comprises the steps of forming cut ends in the desired conductor by means of the plurality of crimp pieces pierced into the desired conductor, each cut end extending along an inner face of a corresponding one crimp piece and in contact with the inner face with a constant pressure over substantially the entire length of the cut end, and inwardly bending the leading ends of the crimp pieces penetrating the flat cable, while maintaining a contact state of the cut ends with the crimp

pieces unchanged.

According to another aspect of the present invention, there is provided a connecting apparatus for connecting a flat cable to a connecting terminal, in which the connecting apparatus connects a flat cable having a plurality of flat conductors arranged in parallel and having surfaces covered with an insulating material to a connecting terminal by piercing a plurality of crimp pieces, formed integrally with a substrate of the connecting terminal, into a desired conductor of the flat cable, and by inwardly bending leading ends of the crimp pieces penetrating the flat cable to hold the desired conductor therebetween. The connecting apparatus comprises a receptacle on which the flat cable held at a predetermined position is placed, the receptacle having a pair of receiving grooves for receiving the crimp pieces, and a bending recess for bending the leading ends of the crimp pieces; an urging member having an urging tool, disposed opposite the receptacle with the flat cable interposed therebetween, for urging the substrate of the connecting terminal, and a guide member for guiding movements of the urging tool; first driving means having elevating means for moving the receptacle up and down, and a moving means for moving the receptacle to selectively place the receiving groove or the bending recess of the receptacle to opposite the connecting terminal; second driving means for urging the urging tool toward the substrate; and control means for controlling the operation of the connecting apparatus.

Preferably, the receptacle has a partition formed with the pair of receiving grooves, and the partition comprises a pressurizing incline plane at an entrance of each of the receiving grooves for forming cut ends in the desired conductor by means of the crimp pieces pierced into the desired conductor, each cut end extending along an inner

face of a corresponding one crimp piece and in contact with the inner face with a constant contact pressure over substantially the entire length of the cut end.

Preferably, the urging member comprises a first sensor for detecting a load acting on the crimp pieces when the substrate is urged by the urging tool to pierce the crimp pieces into the flat cable, and a second sensor for detecting a displacement amount of the crimp pieces with a movement of the urging tool, wherein information detected by both the sensors is output to the control means.

Preferably, the control means receives load information from the first sensor and displacement amount information from the second sensor, and determines a connecting state of the crimp pieces to the conductor when the flat cable is connected to the connecting terminal.

Preferably, the receptacle comprises a top dead center position adjusting mechanism for adjusting a top dead center position of the receptacle.

Preferably, the urging member comprises a bottom dead center position adjusting mechanism for adjusting a bottom dead center position of the urging tool.

According to another aspect of this invention, there is provided a connecting state determining method for determining a connecting state of a connecting terminal to a flat cable having a plurality of flat conductors arranged in parallel and having surfaces thereof covered with an insulating material, in which the connecting state is determined when a desired conductor of the flat cable is connected to the connecting terminal by piercing a plurality of crimp pieces formed integrally with a substrate of the connecting terminal into the desired conductor and by inwardly bending leading ends of the crimp pieces penetrating the flat cable to hold the desired conductor therebetween. The connecting state determining method

comprises the step of determining the connecting state of the crimp pieces to the desired conductor by comparing a piercing load determined when the crimp pieces are pierced into the flat cable and a normal piercing load determined in advance and observed when crimp pieces are normally pierced into a flat cable.

Preferably, the piercing load is determined based on a difference between a maximum load and a minimum load acting on the crimp pieces measured when the crimp pieces are pierced into the flat cable, the minimum load being measured after the maximum load is reached.

The foregoing and other objects, features and advantages of the present invention will become more apparent from the following detailed description based on the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is diagram generally showing a connecting apparatus for connecting a flat cable to a connecting terminal;

Fig. 2 is a front view of another receptacle for use in the connecting apparatus of Fig. 1;

Figs. 3A to 3G are process charts for explaining a method of connecting a flat cable to a connecting terminal according to a first embodiment of the present invention, showing a process of connecting the flat cable to the connecting terminal using the connecting apparatus of Fig. 1;

Fig. 4 is a cross-sectional view showing how a connecting terminal is pierced by an urging member utilizing a receptacle;

Fig. 5 is a cross-sectional view showing how leading ends of crimp pieces are bent utilizing a bending recess of the receptacle;

Fig. 6 is a perspective view showing an example of a flat cable to which a connecting terminal is connected;

Fig. 7 is a cross-sectional view of a flat cable to which a connecting terminal is connected by bending leading ends of crimp pieces in accordance with the method of the present invention;

Fig. 8 is a cross-sectional view of a flat cable to which a connecting terminal is connected by bending leading ends of crimp pieces in accordance with a conventional method;

Fig. 9 is a graph showing a contact resistance of a conductor with a connecting terminal which is measured after a vibration test was conducted for a flat cable to which the connecting terminal is connected;

Fig. 10 is a cross-sectional view showing a receptacle for use in a method of connecting a flat cable to a connecting terminal according to a second embodiment of the present invention;

Fig. 11 is a cross-sectional view showing the relationship between a pressurized incline plane formed on the receptacle of Fig. 10, a conductor of a flat cable, and a crimp piece of a connecting terminal;

Fig. 12 is a graph showing the result of measurement on a contact resistance while a thermal shock test was conducted to a sample of a flat cable to which a connection terminal was connected;

Fig. 13 is a load change characteristic diagram showing the relationship between a load acting on a crimp piece and a displacement amount of the crimp piece in a normal state in which the crimp piece is properly pierced into a flat cable;

Figs. 14A and 14B are model diagrams showing positional relationships between an opening formed in a conductor of a flat cable, a crimp piece, and the conductor;

Fig. 15 is a load change characteristic diagram of a measured piercing load to a displacement amount of a crimp piece in a variety of samples of a flat cable to which a connecting terminal is connected;

Fig. 16 is a cross-sectional view for explaining a gap between a crimp piece and a receiving groove of a receptacle;

Fig. 17 is a perspective view of a flat cable;

Fig. 18 is a perspective view of a connecting terminal; and

Fig. 19 is a perspective view of another connecting terminal.

DETAILED DESCRIPTION

In the following, a method of connecting a flat cable to a connecting terminal, a connecting apparatus, and a connecting state determining method according to one embodiment of the present invention will be described in detail with reference to Figs. 1 through 16.

First, the connecting apparatus for embodying the method of connecting a flat cable to a connecting terminal will be described with reference to Fig. 1.

The connecting apparatus 10 comprises a receptacle 11; an urging member 13; a first elevating press 15; a switching cylinder 16; a second elevating press 17; and a controller 20. The apparatus 10 is used for connecting a connecting terminal 3 or 5 to a desired conductor 1a of a flat cable 1.

The receptacle 11 is formed with a pair of receiving grooves 11a for receiving a plurality of crimp pieces 5b provided on respective sides of the connecting terminal 5; and bending recesses 11b for bending leading ends of a plurality of crimping pieces 5b. The receptacle 11 comprises a top dead center adjusting mechanism 12. The receptacle 11 is arranged below the flat cable 1 held by left and right

chucks 19.

The receptacle 11 is employed for the connecting terminal 5 shown in Fig. 19 which has crimp pieces 5b alternately arranged thereon. A receptacle 25 is used for the connecting terminal 3 shown in Fig. 18 which has crimp pieces 3b arranged opposite to each other. As shown in Fig. 2, the receptacle 25 is formed with a pair of receiving grooves 25a for receiving the crimp pieces 3b, and two bending recesses 25b for bending leading ends of the crimp pieces 3b.

The top dead center adjusting mechanism 12, which adjusts the top dead center of the receptacle 11, has an adjusting screw 12b screwed into a cramping member 12a; a top dead center setting member 12c having a tapered bottom surface; and a stopper member 12d having a tapered top surface. As the adjusting screw 12b is rotated, the top dead center setting member 12c moves horizontally, to change a position at which the tapered surface of the stopper member 12d is in contact with the tapered surface of the top dead center setting member 12c, to thereby adjust a vertical position of the receptacle, i.e., a position of the receptacle relative to the top dead center of the receptacle 11.

The urging member 13, arranged opposite to the receptacle 11 with a flat cable 1 interposed therebetween, has an urging tool 13a and a guide member 13b, and is provided with a bottom dead center adjusting member 14 for adjusting the bottom dead center of the urging tool 13a. The urging tool 13a urges a substrate 5a of the connecting terminal 5. The guide member 13b guides movements of the urging tool 13a.

The bottom dead center adjusting mechanism 14 has an adjusting screw 14b screwed into a cramping member 14a; a top dead center setting member 14c having a tapered top

surface; and a stopper member 14d having a tapered bottom surface. Similar to the top dead center adjusting mechanism 12, the adjusting mechanism 14 adjusts a vertical position of the stopper member 14d, i.e., a position thereof relative to the bottom dead center of the urging tool 13a.

The first elevating press 15 moves up and down the receptacle 11 with respect to the flat cable 1.

The switching cylinder 16 moves the first elevating press 15 in the horizontal direction together with the receptacle 11 to selectively dispose the receiving grooves 11a or bending recesses 11b to a position opposite to the urging tool 13a.

The second elevating press 17 is an actuator for moving the urging tool 13a up and down, and is provided with a load cell 17b on a rod 17a coupled to the urging tool 13a. A displacement amount sensor 18 is disposed in the vicinity of the press 17. The load cell 17b detects a load acting on the crimp pieces 3b or 5b when the crimp pieces are pierced into the flat cable 1. The displacement amount sensor 18 reads the amount of movement of the load cell 17b by means of a photosensor, thereby detecting a displacement amount of the crimp pieces 3b or 5b when the urging tool 13a urges the substrate 3a or 5a. Alternatively, the sensor 18 may be provided with a mechanism for mechanically rotating the rod 17a for moving the same up and down and may determine, from the rotational speed of the rod 17a, a feed amount of the rod 17a as the displacement amount of the crimp pieces 3b or 5b.

In the embodiment, the load cell 17b is used to sense a load and the displacement amount sensor 18 is used to detect a displacement amount, but other sensors may be used, such as a piezoelectric transducer element, a capacitive element, and the like.

The controller 20, comprised of a personal computer and

receiving electric signals related to a load and a displacement amount detected by the load cell 17b and displacement amount sensor 18, controls the operation of the connecting apparatus 10 and determines a connecting state of the flat cable 1 to the connecting terminal 3 or 5. The controller 20 displays a change in a load acting on the crimp pieces 3b or 5b to a displacement amount of the crimp pieces 3b or 5b on a monitor 20a based on the electric signals related to the load and displacement amount output from the load cell 17b and displacement amount sensor 18. The controller 20 determines, as described later, a connecting state based on a piercing load (i.e., a difference between a maximum load and a minimum load) acting on the crimp pieces 3b or 5b when the crimp pieces are pierced into the flat cable 1. A load acting on the crimp pieces varies as a function of displacement of the crimp pieces pierced into the flat cable.

The connecting apparatus 10 configured in the above manner is used to connect the connecting terminal 3 or 5 to the flat cable 1 in a connecting method described below.

In the following, a method of connecting a flat cable to a connecting terminal according to a first embodiment of the present invention will be described with reference to Figs. 3 through 9. The connecting apparatus 10 uses the receptacle 25 in place of the receptacle 11.

First, as shown in Fig. 3A, a flat cable 1 and a connecting terminal 3 are disposed at predetermined positions between the urging member 11 and receptacle 25. As shown in Fig. 4, the flat cable 1 is placed on the receptacle 25, and a desired conductor 1a to be connected is positioned in alignment with the pair of receiving grooves 25a. The flat cable 1 is held by the chucks 19 on both sides of the receptacle 25, as shown in Fig. 1. The connecting terminal 3 is coupled to a coupling piece (not shown) which

is supported by a supporter (not shown).

Next, as shown in Fig. 3B, the receptacle 25 is moved up in contact with the bottom surface of the flat cable 1. At this time, the plurality of crimp pieces 3b oppose the pair of receiving grooves 25a.

Next, as shown in Fig. 3C, the urging member 13 is moved down while the urging tool 13a is pressed down by the second elevating press 17 with the guide member 13b serving as a guide. In this way, the urging tool 13a urges the substrate 3a to pierce crimp pieces 3b into the flat cable 1. As a result, the flat cable 1 is formed at the conductor 1a with cut ends 1c by means of piercing crimp pieces 3b. The cut ends 1c extend along the inner faces, opposite to each other, of the crimp pieces 3b and are in contact with the inner faces of the crimp pieces 3b with a constant contact pressure over substantially their entire length.

As shown in Fig. 4, the crimp pieces 3b are pierced into the conductor 1a with a gap G left between their substrates 3a and flat cable 1. In this way, the crimp pieces 3b are electrically connected to the cut ends 1c of the conductor 1a at contact positions P1, as shown in Fig. 5.

Subsequently, as shown in Fig. 3D, the urging member 13 and receptacle 25 are detached from the flat cable 1 in the vertical direction. To this end, the receptacle 25 is moved down, as indicated by an arrow A in Fig. 4, by the first elevating press 15 to release the crimp pieces 3b from the pair of receiving grooves 25a. Since the flat cable 1 is held at two points by the chucks 19, the contact positions P1 of the crimp pieces 3b with the conductor 1a are kept unchanged.

Next, as shown in Fig. 3E, the receptacle 25 is moved horizontally from the position shown in Fig. 3D to place the two bending recesses 25b opposite to the crimp pieces 3b. Specifically, the receptacle 25 is moved horizontally to the

left by the switching cylinder 16 as indicated by an arrow B in Fig. 4. In parallel with this, the urging member 13 is moved down to a bottom dead center PL at which the urging tool 13a comes in contact with the substrate 3a.

Next, as shown in Fig. 3F, the receptacle 25 is moved up from the position shown in Fig. 3E to a top dead center PU. More specifically, the receptacle 25 is moved upward, as indicated by an arrow C in Fig. 4, by the first elevating press 15, while maintaining the contact positions P1 of the crimp pieces 3b to the conductor 1a unchanged.

In this way, the crimp pieces 3b are urged simultaneously by both the urging tool 13a close to the substrate 3a and the bending recesses 25b close to the leading ends of the crimp pieces 3b. Thus, the leading ends of the crimp pieces 3b are bent while they are curved in an arc shape along the bending recesses 25b. At this time, an urging force is imparted to the urging tool 13a from the second elevating press 17. An urging force for urging the substrate 3a is set to be larger than an urging force with which the receptacle 25 urges the leading ends of the crimp pieces 3b.

Subsequently, as shown in Fig. 3G, the urging member 13 and receptacle 25 are detached upward from the flat cable 1, and the flat cable 1 is released from the chucks 19 to complete the operation for connecting the connecting terminal 3 to the flat cable 1. Fig. 6 shows an example of the flat cable 1 to which the connecting terminal 3 is connected in the foregoing manner.

In the meantime, only the receptacle 25 may be moved from the state shown in Fig. 3C through the steps of Figs. 3D and 3E to the step of Fig. 3F.

As a result, the flat cable 1 is connected to the connecting terminal 3, as shown in Fig. 7, and a bent portion 3d arcuately curved and formed at the leading end of

each crimp piece 3b overlaps the contact position P1 at which the crimp piece 3b is in contact with the cut end 1c of the conductor 1a. Thus, the flat cable 1 and the connecting terminal 3 are retained in a state where a large contact load is applied to the bent portion 3d and the contact position P1.

More specifically, the flat cable 1 is held by the chucks 19 at two points, and the crimp pieces 3b are urged simultaneously from the urging tool piece 13a and from the leading ends of the crimp pieces 3b. Thus, the flat cable 1 is connected with the connecting terminal 3, while maintaining the contact position P1 of the crimp piece 3b and the cut end 1c unchanged. Therefore, the cut end 1c of the conductor 1a and the crimp piece 3b of the connecting terminal 3 are retained in a state they are applied with a high contact load, thereby providing a stable electric connection between the conductor 1a and crimp piece 3b.

However, if the crimp pieces 3b are pierced into the conductor 1a until the substrate 3a comes in contact with the flat cable 1, a stable electric connection cannot be provided between the crimp pieces 3b and conductor 1a, even if the subsequent step of bending the leading ends of the crimp pieces 3b is performed in a manner similar to the above. Specifically, as shown in Fig. 8, the bent portion 3e of the crimp piece 3b does not overlap the contact position P2 at which the crimp piece 3b is in contact with the cut end 1c of the conductor 1a. For this reason, a significantly reduction is caused in contact load applied to the conductor 1a and the crimp piece 3b, thus failing to provide a stable electric connection therebetween.

In case that the crimp piece 3b penetrating the flat cable 1 is properly pierced into the conductor 1a with a gap G (=1.0 mm) left between the substrate 3a and flat cable 1, the leading ends of the crimp pieces 3b are arcuately bent,

while involving the cut end 1c, with the bent portion 3d overlapping the contact position P1 between the crimp piece 3b and the cut end 1c of the conductor 1a. As a result, a larger contact load is applied to the conductor 1a and the crimp piece 3b.

On the other hand, when a projecting amount of the crimp piece 3b from the flat cable 1 is too large, the bent portion 3e of the crimp piece 3b does not overlap the contact position P2 between the crimp piece 3b and the cut end 1c of the conductor 1a. For this reason, the crimp piece 3b cannot involve the cut end 1c when its leading end is bent, resulting in a reduction in the contact load applied to the conductor 1a and the crimp piece 3b.

Such a difference in the connecting state between the flat cable 1 and the connecting terminal 3 can be confirmed in the following manner.

Ten flat cables 1 and ten connecting terminals 3 were prepared. Each flat cable 1 was approximately 0.35 mm in thickness with a conductor 1a of 0.15 mm in thickness and 2.5 mm in width Wc covered with an insulating material formed of a polyethylene terephthalate (PET) film. Each connecting terminal 3 was provided with crimp pieces 3b of approximately 2.3 mm long arranged on both sides in the width direction of a substrate 3a of 2.0 mm in width Wt.

For a set of five flat cables, the crimp pieces 3b were pierced into the conductor 1a with a gap G (=1.0 mm) left between the substrate 3a and flat cable 1, and the leading ends of the crimp pieces 3b were arcuately curved. For another set of five flat cables, the crimp pieces 3b were pierced into the conductor 1a without any gap between the substrate 3a and flat cable 1, and the leading ends of the crimp pieces 3b were arcuately curved. These two sets of flat cables 1 each connected with the connecting terminal were left at a high temperature (=100 °C) for 120 hours in

consideration of use environments, and a contact resistance value between the conductor 1a and the connecting terminal 3 was measured for each flat cable after conducting a vibration test in which vibration is applied to the flat cable in three directions of front-rear, left-right, and up-down under conditions of 4.5 G, 20 Hz - 200 Hz, and a sweeping time of 3 minutes. The result is shown in Fig. 9, where G1 shows when the gap G was left between the substrate 3a and flat cable 1, and G0 shows when no gap G was left.

According to the result shown in Fig. 9, it was found that a change in contact resistance is smaller when the flat cable 1 was connected to the connecting terminal 3 by the method of the present invention with the gap G left between the substrate 3a and flat cable 1 (G1 in Fig. 9), as compared with the case where no gap was left (G0 in Fig. 9). This indicates that the present invention makes it possible to achieve a stable connection, without causing variations.

Next, the method of connecting a flat cable to a connecting terminal according to a second embodiment of the present invention will be described with reference to Figs. 10 through 12.

In a connecting apparatus 10 to which the connecting method of this embodiment is applied, a receptacle 27a shown in Fig. 10 is used in place of the receptacles 11, 25.

The receptacle 27 has a partition 27c formed with a pair of receiving grooves 27a, as shown in Fig. 10. The partition 27c is provided with pressurizing incline planes 27d at an entrance of receiving grooves 27a. As shown in Fig. 11, cut ends 1c are formed in a conductor 1a by means of the pressurizing incline planes 27d in cooperation with the crimp pieces 3b pierced into the conductor 1a. Each cut end 1c extends along the inner face of the crimp piece 3b and is in contact with the inner face of the crimp piece 3b with a constant contact pressure over substantially the entire

length of the cut end. The pressurizing incline plane 27d, which is continuous to the receiving groove 27a, is formed by chamfering the ridge on the upper edge of the partition 27c into an arcuate surface. An inclination angle of the pressurizing incline plane 27d depends on the materials of the crimp piece 3b and conductor 1a, the shape of the crimp pieces 3b, the thickness of the conductor 1a, and the like, and is not uniquely determined.

In Figs. 10 and 11, only the conductor 1a of the flat cable 1 is shown, and the insulating material 1b is omitted.

In the connecting method of this embodiment, the receptacle 27 is used to pierce the crimp pieces 3b of the connecting terminal 3 into a desired conductor 1a of the flat cable 1. Due to the provision of the pressurizing incline planes 27d of the partition of the receptacle 27, the conductor 1a is formed with the cut ends 1c which extend along the inner faces of the crimp pieces 3b, as shown in Fig. 11, and which are in contact therewith over substantially the entire length thereof with a constant contact pressure. For instance, the cut end 1c is in contact with the crimp piece 3b at several points, e.g., three points P3 to P5. Contact pressures at these points P3 to P5 are the same from one another. Therefore, the connecting terminal 3 is connected to the flat cable 1 in a stable state, without causing variations in contact resistance.

Next, after the leading ends of the crimp pieces 3b penetrating the flat cable 1 are released from the receiving grooves 27a, the leading ends are bent and arcuately curved by a bending recess, not shown, while maintaining cut ends 1c in contact with the crimp pieces 3b, whereby the connecting terminal 3 is connected to the flat cable 1.

Therefore, according to the connecting method of this embodiment using the receptacle 27, the conductor 1a can be connected to the plurality of crimp pieces 3b in a stable

state with less variations in contact resistance.

The connecting apparatus which embodies the connecting method of this embodiment uses the receptacle 27 having the pressurizing incline planes 27d. Thus, the cut ends 1c formed in the conductor 1a when the crimp pieces 3b are pierced thereinto can be brought into contact with the inner faces of the crimp pieces 3b with a constant contact pressure over substantially the entire length of the cut ends. Therefore, according to this embodiment, it is possible to provide a connecting apparatus for connecting the flat cable to the connecting terminal in a stable connecting state with less variations in contact resistance of the crimp pieces 3b to the conductor 1a.

This was confirmed by conducting a thermal shock test in which samples S1-S3 each having a flat cable connected to a connecting terminal were subject to 1,000 cycles of thermal shock in a range of +80 °C to -30 °C.

Specifically, the sample S1 was fabricated in accordance with the method of this invention, in which a connecting terminal 3 having a substrate 3a of 2.1 mm in width Wt and a crimp piece 3b of 0.25 mm in thickness was connected to an insulation extruded type flat cable 1 having a conductor 1a of 0.15 mm in thickness and 2.5 mm in width Wc covered with an insulating material 1b made of a polybuthylene terephthalate film (PBT). The sample S2 was fabricated by connecting a flat cable 1 to a connecting terminal 3, which were the same kinds as those of sample S1, in accordance with the conventional method modified by shifting a position, at which a crimp piece 3b was pierced, from the center of the receiving groove 27a in the width direction of the groove. The sample S3 was fabricated by piercing the crimp pieces 3b into a flat cable 1 using a conventional receptacle other than the receptacle 27.

The result of the test is shown in Fig. 12. As is

apparent from Fig. 12, it is found that the use of the receptacle 27 is essential in the connecting method and the connecting apparatus 10 of this embodiment in order to provide a stable connecting state with less variations in contact resistance. Specifically, the sample S1 connected using the receptacle 27 shows a stable connecting state with less variations in contact resistance than the sample S2 based on the conventional method. Although the sample S1 uses the insulation extruded type flat cable 1, it shows stable performance, with less variations in contact resistance, equivalent or superior to the conventional flat cable which uses a polyethylene terephthalate (PET) film as the insulating material 1b.

Next, a method of determining a connecting state of the flat cable 1 to connecting terminal 5, connected using the connecting apparatus 10 shown in Fig. 1 based on the aforementioned connecting method, will be described with reference to Figs. 13 through 16.

According to the findings of the present inventors, the connecting state of the conductor 1a to the crimp piece 5b when the flat cable 1 is connected to the connecting terminal 5, largely depends on a contact load (N) with which the cut end 1c of the conductor 1a is in contact with the crimp piece 5b. In other words, pass/fail of the connecting state of the conductor 1a to the crimp piece 5b largely depends on a resistive load (N) observed after through-holes extending through the conductor 1a are formed by piercing the crimp pieces 5b into the flat cable 1.

The connecting apparatus 20 is configured to create a load change characteristic diagram when the crimp pieces 5b are pierced into the flat cable 1, with the horizontal axis representing a displacement amount (mm) of the crimp pieces and the vertical axis representing the load (N) acting on the crimp pieces, based on electric signals related to a

load and a displacement amount input from the load cell 17b of the second elevating press 17 and the displacement mount sensor 18.

Fig. 13 shows the load change characteristic created by the connecting apparatus 20 in a normal state in which the crimp pieces 5b of the connecting terminal 5 having the substrate 5a with a width Wt=1.2 mm are properly pierced into the flat cable 1 having the conductor 1a with a thickness of 0.15 mm and a width Wc=1.5 mm.

In Fig. 13, with the increase in displacement of the crimp pieces 5b, the load acting on the crimp pieces increases to a maximum load L1 required for the crimp pieces 5b to penetrate through the entire flat cable 1, and then decreases to a minimum load L3 which corresponds to a friction resistance between the crimp pieces 5b and the conductor 1a. A difference L2 between the maximum load L1 and the load varying depending on the displacement of the crimp pieces represents a piercing load, i.e., a load of a resistance associated with the formation of openings in the conductor 1a by means of the crimp pieces 5b.

A thermal shock test for a flat cable connected with a connecting terminal reveals that the crimp pieces 5b can be connected to the conductor 1a under a stable contact load when the piercing load L2 has a value equal to or less than a buckle threshold value of the crimp pieces 5b.

In Figs. 14A and 14B, with the downward movement of the connecting terminal 5, a relative position of a conductor 1a and a crimp piece 5b of a connecting terminal 5 changes. When a relative position K1 is assumed, an opening H1 having a width of 2t1 is formed in the conductor 1a. As the connecting terminal 5 is further moved down, the width of the opening in the conductor gradually increases. When the tapered portion of the crimp piece 5b passes through the entire conductor 1a, an opening H2 having a width of

2(t1+t2) is formed. Subsequently, the width 2(t1+t2) of the opening is kept unchanged although the connecting terminal 5 is further moved downward. Symbol K2 denotes, by way of example, a relative position of the conductor 1a and the crimp piece 5b after the tapered portion passes through the conductor.

In actually connecting the flat cable 1 to the connecting terminal 5, the piercing load L2 is determined and compared with a normal piercing load serving as the criteria to determine a connecting state. The normal piercing load, which is determined in advance during the fabrication of non-defective products, varies in a range from 150N to 220N, for instance. Thus, pass/fail of a connecting state is determined by making a determination as to whether or not the piercing load L2 determined during the actual connecting operation falls with in a range, e.g., from 150N to 220N.

Fig. 15 is a load change characteristic diagram of a measured piercing load to a displacement amount of the crimp pieces 5b in a variety of samples S4 to S7.

The sample S4 is an actually measured result in the normal state described in connection with Fig. 13, where the piercing load L21 is approximately 180N.

The sample S5 is an actually measured result in a defective state, where the piercing load is L22. Here, the defective state may be, for example, the crimp pieces 5b not properly inserted into the receiving grooves 11a, or the crimp pieces 5b pierced into the flat cable 1 with a gap g between crimp pieces 5b and partition 11c larger than normal, as shown in Fig. 16. When the gap g is larger than normal, a contact load between the cut end 1c of the conductor 1a and the crimp piece 5b is reduced.

The sample S6 is an actually measured result when a residue of the insulating material 1b or foreign substances

clog between the receiving grooves 11a and flat cable 1 to cause an abnormally large contact load between the crimp pieces 5b and the cut end 1c of the conductor 1a.

The sample S7 is an actually measured result when the crimp pieces 5b cannot penetrate the flat cable 1 and are buckled due to foreign substances introduced into the receiving grooves 11a, defective receiving grooves 11a, defective thicknesses of the conductor 1a and insulating material 1b, and the like.

In this way, a variety of defective states which could occur in connecting the flat cable 1 to the connecting terminal 5 can be simply detected based on the piercing load change characteristic to a displacement amount of the crimp pieces 5b. Therefore, by comparing such cases with the normal state with respect to the piercing load, it is possible to quite easily determine a connecting state of the flat cable 1 to the connecting terminal 5.

When the pair of receiving grooves 11a wear, a measured piercing load changes. Therefore, in the connecting state determining method of this embodiment, it is also possible to determine the wear of the receiving grooves 11a, and hence the lifetime of the receptacle 11 based on a change in this load.

While the connecting state determining method of this embodiment has been described in connection with the connecting terminal 5, a similar determination can be made as well when the connecting terminal 3 is used.